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Title: Electromagnetic Time Reversal (EMTR) For discrete source identification

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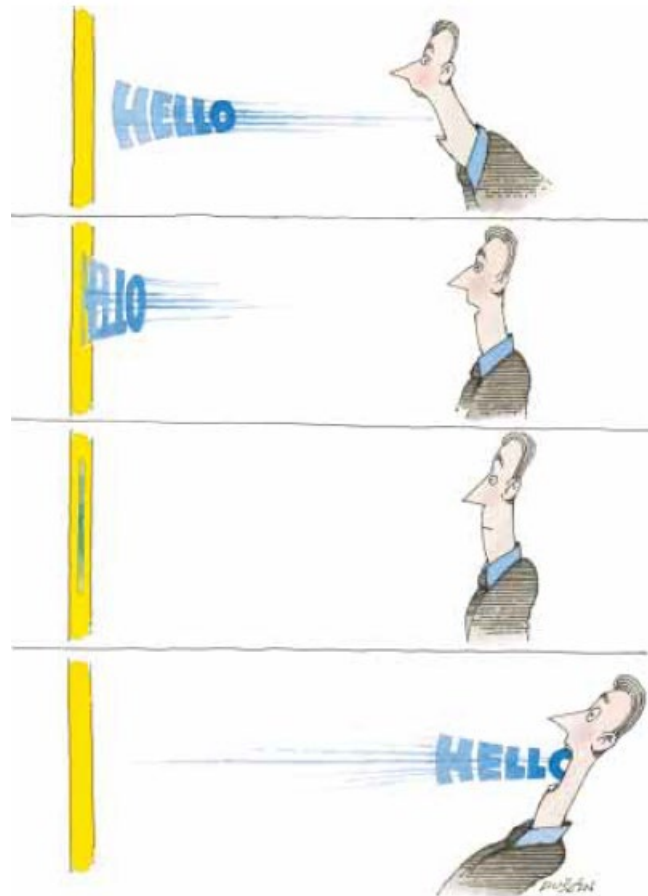
# Electromagnetic Time Reversal (EMTR)

For discrete source identification

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(LANL), T. J. Ulrich (LANL)



# Acoustic TR



Fink, Mathias. "TIME-REVERSED ACOUSTICS." *Scientific American*, vol. 281, no. 5, 1999, pp. 91–97.

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# What is time reversal

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- Signal processing technique that relies on the principle of wave reciprocity
- Applications: Fault detection, wireless power transfer etc.
- Wave equation is time invariant

$$\nabla^2 E - \frac{1}{c^2} \frac{\partial^2 E}{\partial t^2} = 0$$

- Both  $E(t)$  and  $E(-t)$  are solutions due to second order derivatives

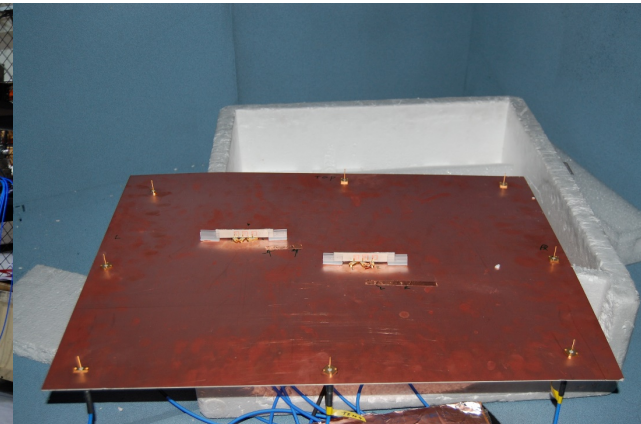
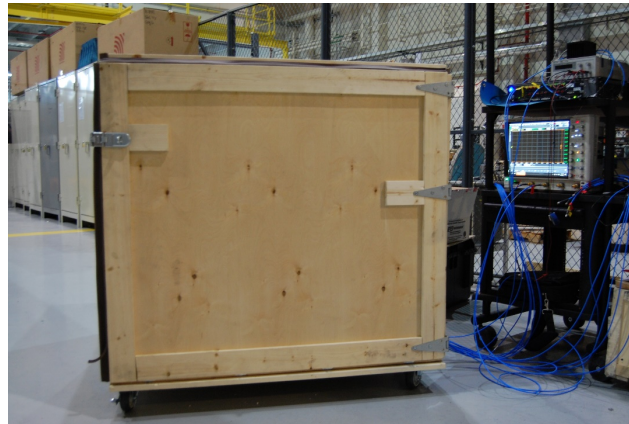
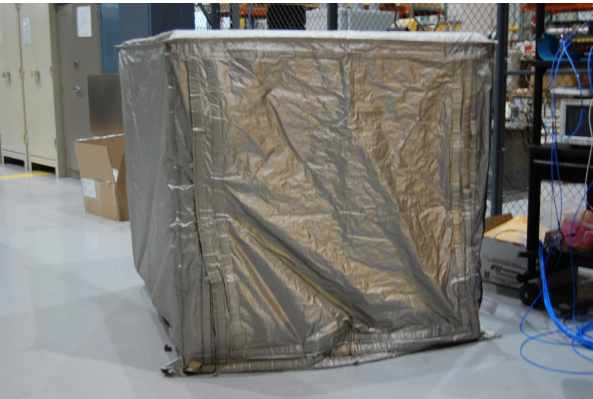
# Motivation- EMTR at LANL

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- Perform source diagnostics
- Characterize sources/events with subwavelength resolution

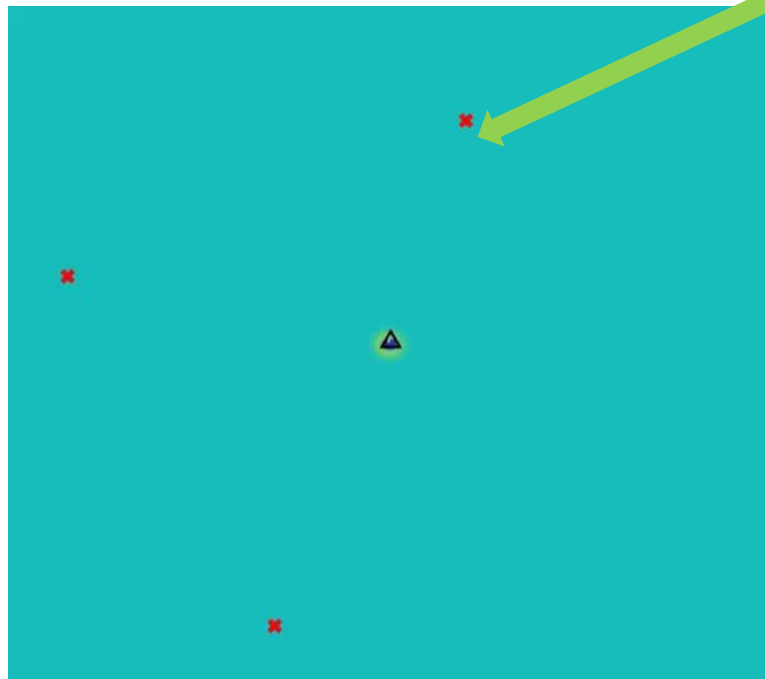
# EMTR at LANL

- Successfully demonstrated time reversal using RF waves
- A dedicated test bed, portable anechoic chamber was built for TR experiments
- Multiple sources within the operating bandwidth were characterized
- Numerical simulations and the laboratory measurements agree closely.



# How Time Reversal works

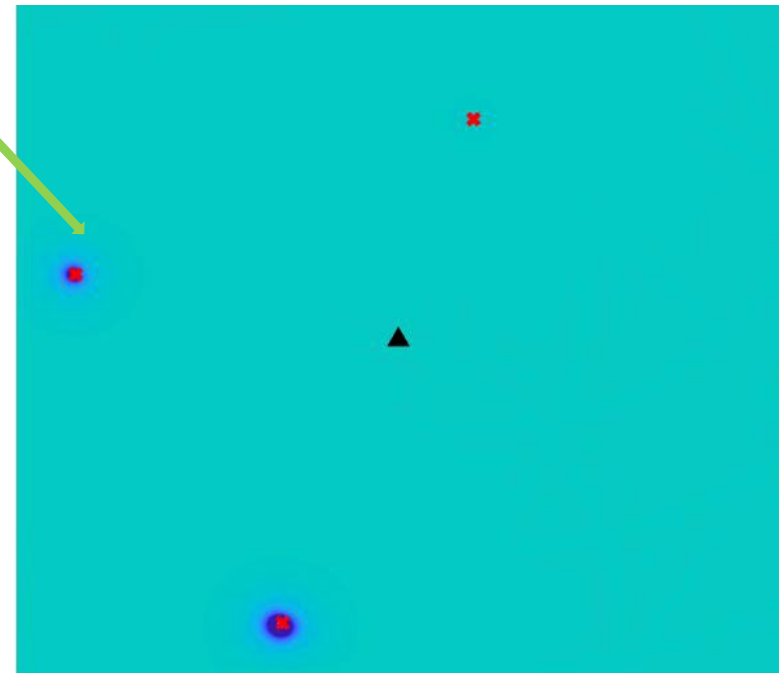
TIME REVERSAL MIRROR (TRM)



I. Forward propagation



II.  
Numerically  
reverse the  
received  
signals

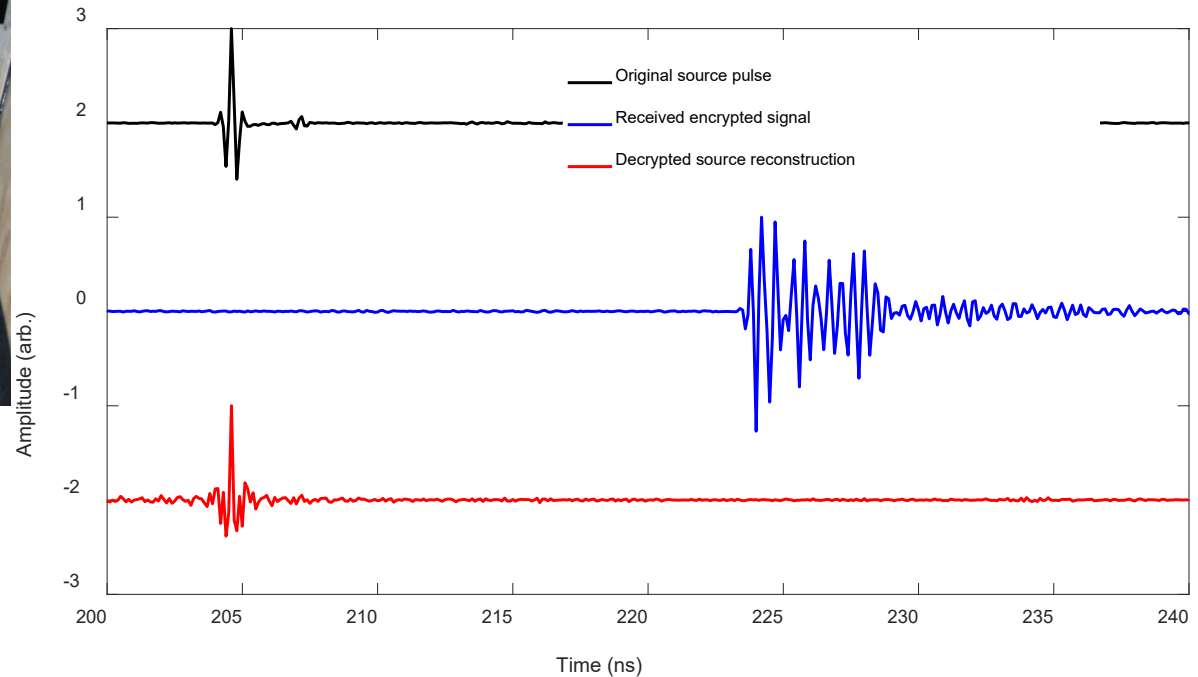
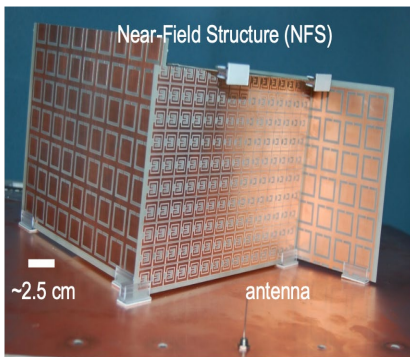
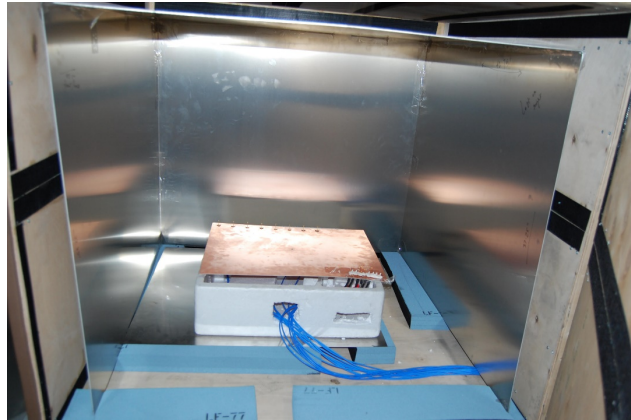


III. Backward Propagation

TR is a three step process



# TR measurements (1- 4 GHz)



Single source signal reconstruction – only a time measurement.

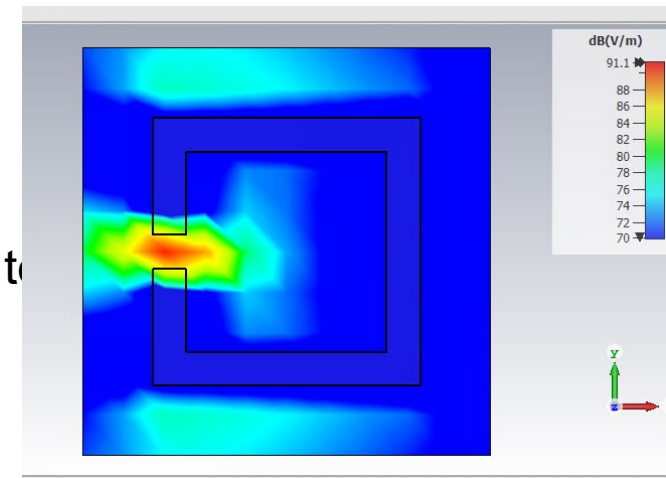
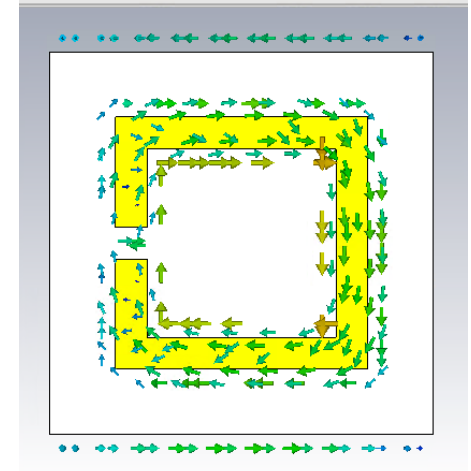
No spatial discrimination

# Electromagnetic time reversal with subwavelength resolution

- TR is diffraction limited
- Super resolution shown through loops<sup>1</sup>, rods<sup>2</sup> etc. -typically single excitation
- I am using frequency selective resonators to get discrete subwavelength resolution.

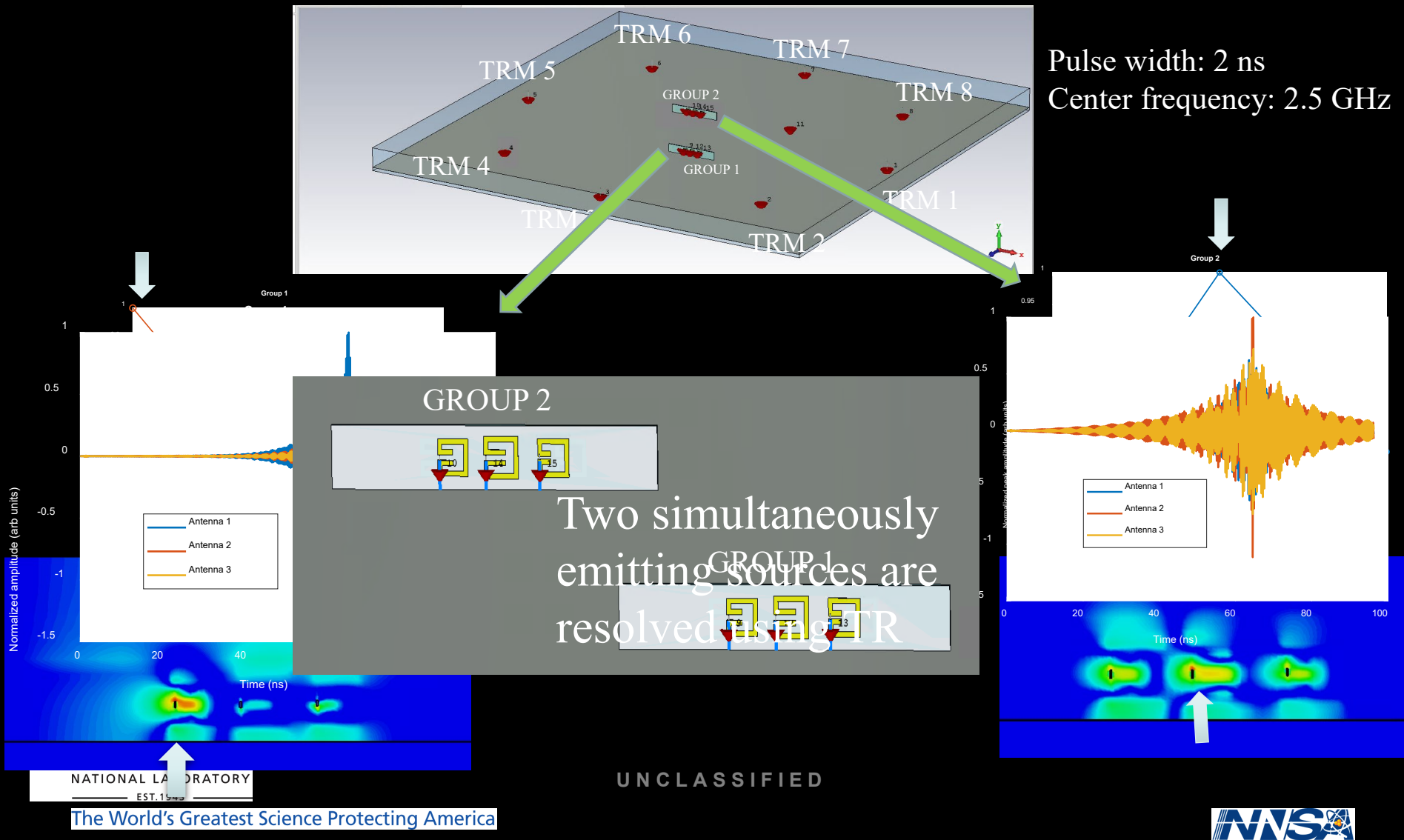
## Split ring resonators (SRR)

- Near-field to far-field conversion
- Field enhancement at the gap
- Strong frequency selection
- discrete and physically small compared to wavelength

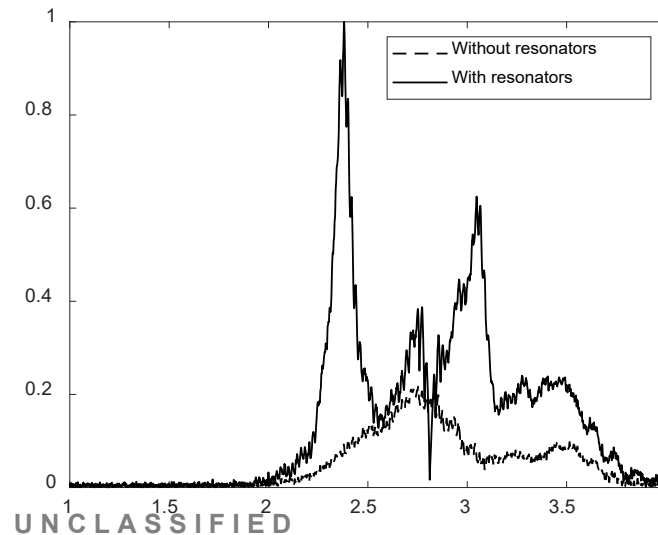
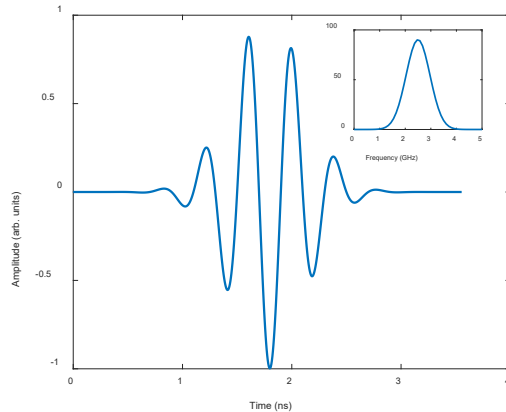


# Subwavelength detection using near field resonator/scatterer

## Example: Two simultaneous excitations (Simulation)



# Subwavelength detection using near field resonator/scatterer (measurements)



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